

FIG. 5A.5E

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METHOD OF AND APPARATUS FOR HORIZONTAL WELL DRILLING
Technical Field of the Invention

This invention relates to a method and apparatus for horizontal drilling into the earth strata surrounding a well casing. More specifically, the present invention relates to a method and apparatus for drilling through the walls of a vertically extending well casing at a 90° angle to provide horizontal drilling into the earth's strata for a substantial distance radially from the vertically extending well casing.

Background Art

Oil and gas wells are drilled by the use of rotary drilling equipment vertically into the earth's strata. The vertically extending well holes generally include a casing usually of mild steel in the neighborhood of 4 1/2 inch (11.4 cm) to 8 inch (20.3 cm) in diameter which define the cross-sectional area of a well for transportation of the oil and gas upwardly to the earth's surface. However, these vertically extending wells are only useful for removing oil and gas from the general vicinity adjacent to and directly underneath the terminating downward end of the well. Thus, not all of the oil and gas in the pockets or formations in the earth's strata, at the location of the well depth, can be removed. Therefore, it is necessary to either make other vertical drillings parallel and close to the first drill, which is timely and costly, or provide means to extend the original well in a radial or horizontal direction. The most common means for horizontal extension of the well has been to drill angularly through the well casing at a first 45° angle for a short distance and then to turn the drill and drill at a second 45° angle thereby making a full 90° angular or horizontal cut from the vertically extending well. These horizontal drills have proved useful for extending the well horizontally. However, most of

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these horizontally extending cuts have proved to be relatively expensive.

There have been a number of patents issued which teach a number of different ideas for accomplishing horizontal drillings or cuttings into the earth's strata surrounding an existing well, but, again, most of these have proved to be costly and have also not produced the desired results. U.S. Patent No. 4,460,362 teaches a method of penetrating a well casing and surrounding earth strata with the use of a punch member for cutting through a well casing wherein the punch member includes a retractable jet nozzle means therein for penetrating the surrounding earth's strata after the punch member has cut through the casing. Other patents which teach drilling components for horizontal extensions from vertically extending wells wherein hydraulic fluid directing nozzles are used in the drilling operations include U.S. Patent No. 2,271,005; U.S. Patent No. 2,345,816; U.S. Patent No. 3,838,736; U.S. Patent No. 3,873,156; and, U.S. Patent No. 4,168,752.

SUMMARY OF THE INVENTION

The present invention is directed to a method and apparatus for penetrating a well casing and surrounding earth strata. Furthermore, the present invention is directed to a method of penetrating a well casing and surrounding earth strata utilizing a two-step process wherein a flexible shaft having a ball cutter on one end thereof is used to make a cut through the well casing and a pre-cut into the earth's strata surrounding the well casing and the second step involves the use of a flexible tube having a nozzle blaster on the end thereof which is then inserted down the well casing into the pre-cut and in combination with a high pressure fluid pumped through the flexible tube and out through the nozzle blaster, a horizontal extension of the pre-cut can then be made up to a

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distance of more than 200 feet (61 m). The upset tubing can then be turned from the surface 90° to repeat the process in another direction. One can then cut another hole through the casing 12 and repeat the process up to 4 directions on one level. Many levels can be opened with the same procedure. This invention has application in drilling oil, gas, or water, for example.

More particularly, the present invention is directed to a method of penetrating a well casing and surrounding earth strata comprising the steps of inserting a flexible shaft having a cutting means on one end thereof into upset tubing in a well casing wherein the upset tubing is provided with an elbow at its terminating end; rotating said flexible shaft and said cutting means thereby cutting a hole in said well casing and the earth's strata surrounding the well casing; removing the flexible shaft and the cutting means from the upset tubing; inserting a flexible tube having a nozzle blaster on an end thereof into the upset tubing and out through the cut in the well casing and the earth's strata; and, pumping fluid at high pressure into the tubing and nozzle blaster thereby cutting an extension of the cut into the earth's strata.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a side elevational view showing a gas or oil well in section and the down hole apparatus of the present invention being used in cutting an opening in the well casing;

FIG. 1B is a side elevational view showing a gas or oil well in section and the down hole apparatus of the present invention being used in extending horizontally the cut in the earth's strata shown in FIG. 1A;

FIG. 2 is an enlarged sectional view of FIG. 1A but with emphasis on the lower portion of the well

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where a cut into the hole casing is to be made;

FIG. 3 is an enlarged perspective view of the cutting ends of the apparatus of FIG. 2;

FIG. 4 is an enlarged elevational view of FIG. 1B with emphasis being placed on the lower end of the well to emphasize the apparatus utilized in drilling an extension into the earth's strata away from the well;

FIG. 5A is an enlarged perspective view of the cutting end of the apparatus of FIG. 4;

FIG. 5B is a perspective view of FIG. 5A with selected portions cut-away, and rotated 90°;

FIG. 6A is an enlarged sectional view similar to the view of FIG. 2, showing a second preferred apparatus for making a cut through a well casing, with emphasis on the lower portion of the well where the cut into the hole casing is to be made;

FIG 6B is an enlarged sectional view similar to FIG 6A, the second preferred apparatus of FIG 6A shown having completed the cut through the well casing;

FIG. 7 shows the lower portion of the upset tubing and the elbow;

FIG. 8A shows an exploded view of the cutter ball connectivity to its operating means for the second preferred apparatus of FIG 6A; and

FIG. 8B shows the cutter ball connected for operation.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1A and FIG. 2 of the drawing shows the employment of a preferred embodiment of the invention in an oil well 10 having a well casing 12 which extends downwardly through the earth's strata 14 into a pocket of oil or gas. FIG. 1A shows the apparatus 16 used in making a cut through the well casing 12.

The apparatus 16 includes upset tubing 18 which extends downwardly through the well casing 12 a preselected distance, the preselected distance being the distance to which a cut into the well casing 12 is

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to be made and the positioning of the terminating end 18a for the horizontal cut into the earth's strata. The upset tubing 18 may be any upset tubing well known in the art, but at the terminating end 18a of the upset tubing 18 is an elbow 20 which is positioned to be rotated to a specific position within the well casing 12 for making the cut therethrough as well as to receive a ball cutter 22 and flexible shaft 24 therethrough. The elbow 20 is generally made from an octagonally-shaped block of metal which with an opening extending therethrough, the inlet 20a and outlet 20b being 90° to each other. Inlet 20a has a larger diameter than the outlet 20b. The upset tubing 18 has an O.D. less than the I.D. of the well casing 12 and is usually made of rolled steel. In a preferred embodiment, the upset tubing is metallic and the terminating end 18a is attached to the elbow 20 by welding at the location noted by the numeral 30. The upset tubing 18 is generally mounted onto the head of the well 32. Located at a down hole position just inside the well is a blow out preventer 34 which is generally well known in the oil and gas drilling art wherein blow out preventers are used to prevent the blow back of materials up through the upset tubing at the well head 32.

The ball cutter 22 is coupled to the flexible shaft 24 on one end and shaft 24 on its opposite end is coupled to a fluid driven motor 38 which is suspended down into the upset tubing 18. Fluid returns through exhaust vent on the motor 38 and then flows between flex tubing 48 and the tubing 18, and carries the fluid for the operation of the fluid driven motor 38. The fluid driven motor 38 is, for example, an Ingersol-Rand Model No. DLO 21B-5-P which is operable in response to 1000 psi (70.3 kilograms/sq cm) of hydraulic pressure as delivered through the fluid tube 48. Fluid driven motor 38 generally turns at 500 rpm.

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However, in the present operation a reducer 42 is attached to the outlet shaft 44 of the motor 38 wherein the reducer 42 reduces the 500 rpm rotating speed down to generally between 40 to 60 rpm. The ball cutter 22 is a tungsten carbide cutter with a roughened surface and in cutting through of the well casing 12 is designed to rotate at a relatively low speed, such as the 40 to 60 rpm noted previously. Operation of the ball cutter 22 of the present invention at a high rate of speed generally makes the cutting through the well casing 12 difficult to control and it has been found that with a rotatable speed of 40 to 60 rpm, the ball cutter can still make a cut in a relatively short period of time, such as in about 15 minutes through a well casing 12 which is 1/8 inch (3.2 mm) thick.

In FIG. 1B a preferred embodiment of the present invention is shown wherein a cut in the well casing 12 is utilized as the starting point for drilling a hole into the earth's strata 14 outwardly from the well casing 12. A nozzle blaster 46 is suspended to the oil well 10 wherein the nozzle blaster 46 is threadably attached to the end of a fluid tube 48. Fluid tube 48 may be of an elastomeric or metallic material, but must be capable of withstanding internal fluid pressures of up to and greater than 4000 psi (281 kgms/sq cm). One preferred tube is a flexible, seamless, stainless steel tubing approximately 0.25 inches (6.35 mm) I.D. and approximately 0.375 inches (9.53 mm) O.D. Alternatively, a flexible, seamless, stainless steel tubing approximately 0.5 inches (12.7 mm) O.D. can be utilized. As best shown in FIGS. 4, 5A, and 5B, the nozzle blaster 46 is provided with a plurality of apertures or nozzles 50 therein, the apertures 50 being dispersed uniformly over the conical portion 46a of the nozzle blaster. The apertures are positioned to provide openings from the inside of the nozzle blaster 46 so that fluid passing from the inside of the nozzle

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46 is directed outwardly away from the well casing 12 at a 45° angle from the longitudinal axis passing therethrough. In the base portion 46b of the conically shaped nozzle blaster 46, the apertures 50 are also
5 disposed at a 45° angle to longitudinal axis to provide high pressure fluid inwardly towards the well casing 12 thereby keeping the channel or cut open as the nozzle 46 moves outwardly away from the well casing. In a preferred nozzle blaster 46, apertures 50 are
10 approximately .026 inch (6.6 mm) in diameter.

As best shown in Fig 1B, the fluid tube 48 at its inlet end is in flow communication with a tank container 54 which includes fluid 56 therein. The container 54 is separate and free standing and tube 48
15 is coiled onto a rotatable drum 60 also mounted on the platform skid 58. The fluid tube 48 is rolled upon or unrolled from drum 60 for use within the oil well 10.

The fluid 56 in the container 54 is generally a mixture of a surfactant and water wherein the
20 surfactant is generally from about 1 to 5% by weight of the total solution. In the drilling operation, the fluid 56 is generally heated in a heat exchanger 62 also mounted on the platform skid 58 which maintains the surfactant water solution in a heated condition.
25 Generally, the temperature of the surfactant water solution is between about 130°F (54°C) and 160°F (71°C). And, the surfactant is generally selected from a group consisting of water wetters, oil wetters, and surfactants with a sodium salt. One preferred
30 surfactant is a product manufactured by Climax Performance Materials Corporation under the trademark ACTRASOL-MY-75 which is a mixture of sulfonated soybean oil, a sodium salt, and a methyl ester of soybean oil.

Also provided on the platform skid 58 is a pump 64
35 which is, for example, Giant Industries, Model Number P450A which will produce a fluid discharge pressure of up to 5000 psi (352 kgms/sq cm), or Landers Horizontal

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Drill Pump which will produce a fluid discharge pressure of up to 10,000 psi (703 kgms/sq cm). Pump 64 mounted onto the platform skid 58 is in fluid communication with the fluid tube 48 for pumping the surfactant water solution 56 from the container 54 into the oil well 10 wherein the high pressure fluid 56 discharges through the openings in the nozzle blaster 46 at 3500 to 4000 psi (246 to 281 kgms/sq cm). And, with continual feeding of the tube 48 down through the upset tubing 18, a horizontal drill or cut into the earth's strata 14 in excess of 200 feet (61 m) away from the well casing 12 is possible. Moreover, the time for making the drill 200 feet (61 m) from the well casing can be expected to be accomplished within 6 to 10 hours.

In operation, the upset tubing 18 having the elbow 20 on the end thereof is lowered into a well casing 12 to a preselected position therein, the position being determined as the location for a horizontal drill into the earth's strata 14. A fluid tube 48 having a fluid driven motor 38 on the terminating end thereof with a reducer 42, flexible shaft 24 and ball cutter 22 extending therefrom is lowered into the well casing 12 until the ball cutter 22 passes out through the elbow 20 until the ball cutter 22 is positioned adjacent to the inside of the well casing 12. Fluid at approximately 1000 psi (70.3 kgms/sq cm) is pumped down through a fluid tube 48 wherein the fluid, which is generally a surfactant-water mixture 56 activates the fluid driven motor 38 and in turn the reducer 42. Reducer 42 turns the flexible shaft 24 thereby rotating the ball cutter 22 at approximately 40 to 60 rpm. Within about 15 minutes the ball cutter 22 cuts through the well casing 12 which is 1/8 inch (3.2 mm) in thickness. After the cut through the casing 12, flexible fluid tube 48 is continually lowered so the ball cutter 22 continues moving outwardly into the

earth's strata for a preselected distance, generally a distance up to 12 inches (25.4 cm) and preferably about 1 ½ inches (3.8 cm) to 2 inches (5.1 cm). The 1 ½ inches (3.8 cm) is generally sufficient for the starting point for the horizontal drilling or extension of the pre-cut into the earth's strata. The ball cutter 22 is then removed from the upset tubing 18 and wound back up onto a drum 66 on the platform skid 58. The fluid tube 48, including the nozzle blaster 46 on the terminating end thereof, is then lowered down into the upset tubing 18 and is continued to be rolled off of the drum 60 until it extends through the elbow 20, through the opening in the well casing 12 which has been made previously by the ball cutter 22, and to the end of the pre-cut into the earth's strata 14 by ball cutter 22. When the nozzle blaster has reached the pre-cut distance from the well casing 12, pump 64 is turned on and the surfactant-water mixture 56 is then pumped at a pressure of 3500 to 4000 psi (246 to 281 kgms/ sq cm) from the container 54 through the heat exchanger 62 down into the oil well 10 and out through the nozzle blaster 46. The high pressure fluid 56 is continually pumped and the tube 48 is continually unwound from the drum 60 until a preselected distance from the well casing 12 is obtained. The high pressure fluid spewing from the nozzle blaster 46 is capable of cutting through the earth's strata including limestone layers and other softer materials without delay and within 6 to 10 hours can blast or cut horizontally at least 200 feet (61 m).

FIGS. 6A-8B show a second preferred apparatus 116 used in making a cut through the well casing 12. As with the embodiment of FIG. 1A, the apparatus 116 includes upset tubing 18 which extends downwardly through the well casing 12 a preselected distance, the preselected distance being the distance to which a cut into the well casing 12 is to be made and the

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positioning of the terminating end 18a for the horizontal cut into the earth's strata. At the terminating end 18a of the upset tubing 18 is elbow 20 which is positioned to be rotated to a specific position within the well casing 12 for making the cut therethrough as well as to receive a ball cutter 122 and flexible shaft 124 therethrough. Again, the terminating end 18a of upset tubing 18 is attached to elbow 20 by welding at the location noted by the numeral 30.

The elbow 20 has an inlet 20a and an outlet 20b being 90° to each other. Inlet 20a has a larger diameter than the outlet 20b. Between inlet 20a and outlet 20b is a "bowed" channel 20c. This bow makes it easier for the cutter assembly, including cutter 122 and the flexible shaft 124 connecting to motor 138, as explained hereinafter, to make the 90° bend from inlet 20a to outlet 20b. The bottom portion of channel 20c has about a 5° upslope toward outlet 20b.

The ball cutter 122 is shown having a shaft 123 extending therefrom. A plurality of preferably stainless steel ball bearings 126 are employed. FIGS. 6A and 6B show seven such balls 126. The endmost ball 126a has opposed bores 130 and 132 for receiving flexible shaft 124 and ball cutter shaft 123 respectively. A bore 134 connects to bore 132 and receives, for example, a threaded set screw 136 to securely retain cutter ball shaft 123 within bore 132. Flexible shaft 124, having for example a diameter of about 5/16 inch (7.9 mm), has one end secured within bore 132. For example, ball 126a can be hydraulically compressed to secure ball 126a onto shaft 124. Balls 126, other than endmost ball 126a, have diametric bores 128 therethrough, sized so that balls 126 will fit over flexible shaft 124. Springs 125 are placed over shaft 124 between the balls 126 to maintain spacing between each of the balls 126. The end of flexible shaft 124

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opposite cutter ball 122 is coupled to a fluid driven motor 138 which is suspended down into the upset tubing 18. As with motor 38 of the first embodiment, fluid returns through exhaust vent on the motor 138 and then
5 flows between flex tubing 48 and the tubing 18, and carries the fluid for the operation of the fluid driven motor 38. With this embodiment, the fluid driven motor 138 is, for example, a Micro Motor Model No. MMF0002, which is operable in response to 110 psi (7.7
10 kilograms/sq cm) of air pressure as delivered through the fluid tube 48. Fluid driven motor 138 generally turns at 225 rpm. Therefore, a reducer is not employed with this model. Ball cutter 122 can make a cut in a relatively short period of time, such as in about 15
15 minutes through a well casing 12 which is 1/4 inch (6.4 mm) thick.

A motor detent insert 143 is secured within the lower portion of upset tubing 18. Motor detent insert 143 has diametrically opposed slots 145 which receive a
20 horizontal detent wing 139 of motor 138. This prevents motor 138 from rotating during operation. For example, insert 143 can be about 12 inches (30.5 cm) in height. Attached within upset tubing 18 about 4 inches (10.2 cm) above insert 143 is a tipper 141. Tipper 141
25 serves to align horizontal detent wing 139 with diametrically opposed slots 145.

It is realized that while the preferred embodiment of the invention has been disclosed herein, further modifications to the preferred embodiment will occur to
30 those skilled in the art and such obvious modifications are intended to be within the scope and spirit of the present invention.

CLAIMS

1. A method for penetrating a well casing and surrounding earth strata comprising the steps of:

- 5 (a) inserting an upset tubing having an elbow on an end thereof a preselected distance into a well casing;
- 10 (b) inserting a flexible shaft having cutting means on an end thereof into said upset tubing, said cutting means extending through said elbow;
- (c) rotating said flexible shaft and said cutting means cutting a hole in said well casing;
- 15 (d) cutting a channel a preselected length in the earth's strata surrounding said well casing;
- (e) removing said flexible shaft and said cutting means from said upset tubing;
- 20 (f) inserting a flexible tube having a nozzle on an end thereof into the upset tubing and said channel;
- (g) pumping a fluid into the flexible tube and nozzle; and,
- (h) cutting an extension of said channel in said earth's strata.

25 2. The method of Claim 1, said flexible shaft being rotated in response to a fluid motor.

3. The method of Claim 1 wherein said cutting of a preselected length into the earth's strata is from about 1 ½ inches (3.8 cm) to 12 inches (25.4 cm).

30 4. The method of Claim 1, said nozzle being a nozzle blaster, conical in shape with a fluid chamber therein in fluid communication with said flexible tube, said nozzle blaster having a conical portion and a base portion, said nozzle blaster having a plurality of

35 openings therein extending into said chamber wherein said openings have a diameter of about 0.026 inch (6.6 mm) and are positioned at an angle of about 45° to the

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longitudinal axis passing through said nozzle blaster.

5. The method of Claim 1 wherein said fluid is a mixture of a surfactant and water.

6. The method of Claim 5 wherein said surfactant
5 is from about 1 to 5% by weight of the surfactant and water mixture.

7. The method of Claim 5 wherein said surfactant is selected from the group consisting of water wetters, oil wetters, and surfactants with a sodium salt.

10 8. The method of Claim 5 wherein said surfactant is a mixture of a sulfonated soybean oil, a sodium salt and a methyl ester of soybean oil.

9. The method of Claim 1, said cutting of an extension of said channel being up to 200 feet (61 m)
15 horizontally from said well casing.

10. An apparatus for cutting a hole in a well casing comprising:

(a) a ball cutter;

(b) a flexible shaft having said ball cutter on
20 one end thereof;

(c) means to rotate said flexible shaft; and,

(d) means to position said ball cutter at a preselected position within a well casing.

11. The apparatus of Claim 10 wherein said means
25 to rotate includes a fluid motor coupled to said flexible shaft.

12. The apparatus of Claim 11 wherein said means to rotate includes a speed reducer coupled to said fluid motor wherein said speed reducer is coupled to
30 said flexible shaft.

13. The apparatus of Claim 12 wherein said output of said speed reducer is from about 40 to 60 rpm.

14. The apparatus of Claim 10 wherein said means
35 to position said ball cutter includes an elbow at the terminating end of an upset tubing in a well casing.

15. The apparatus of Claim 14 wherein said elbow

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is provided with an inlet and outlet opening in flow communication therethrough, said elbow being octagonally shaped wherein said inlet is on one side thereof and said outlet is on another side at 90° angle from said inlet, said opening being larger at said inlet than said outlet.

16. An apparatus for drilling horizontally into the earth's strata from an opening in the well casing comprising:

- 10 (a) a high pressure fluid nozzle blaster;
- (b) a flexible conduit having said nozzle blaster on the end thereof;
- (c) means to transfer fluid at high pressure to said flexible conduit;
- 15 (d) means to position said nozzle blaster in said opening; and,
- (e) means to feed said flexible conduit through said opening.

17. The apparatus of Claim 16 wherein said fluid nozzle blaster is a nozzle blaster having a conical portion and a base portion.

18. The apparatus of Claim 17 wherein said nozzle blaster has a fluid chamber therein and includes a plurality of orifices in said conical portion and said base portion at a 45° angle to the longitudinal axis passing through said nozzle blaster.

19. The apparatus of Claim 16 wherein said fluid is a mixture of a surfactant and water.

20. The apparatus of Claim 19 wherein said surfactant is from about 1 to 5% by weight of the surfactant and water mixture.

21. The apparatus of Claim 19 wherein said surfactant is selected from the group consisting of water wetters, oil wetters, and surfactants with a sodium salt.

22. The apparatus of Claim 19 wherein said surfactant is a mixture of a sulfonated soybean oil, a

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sodium salt, and a methyl ester of soybean oil.

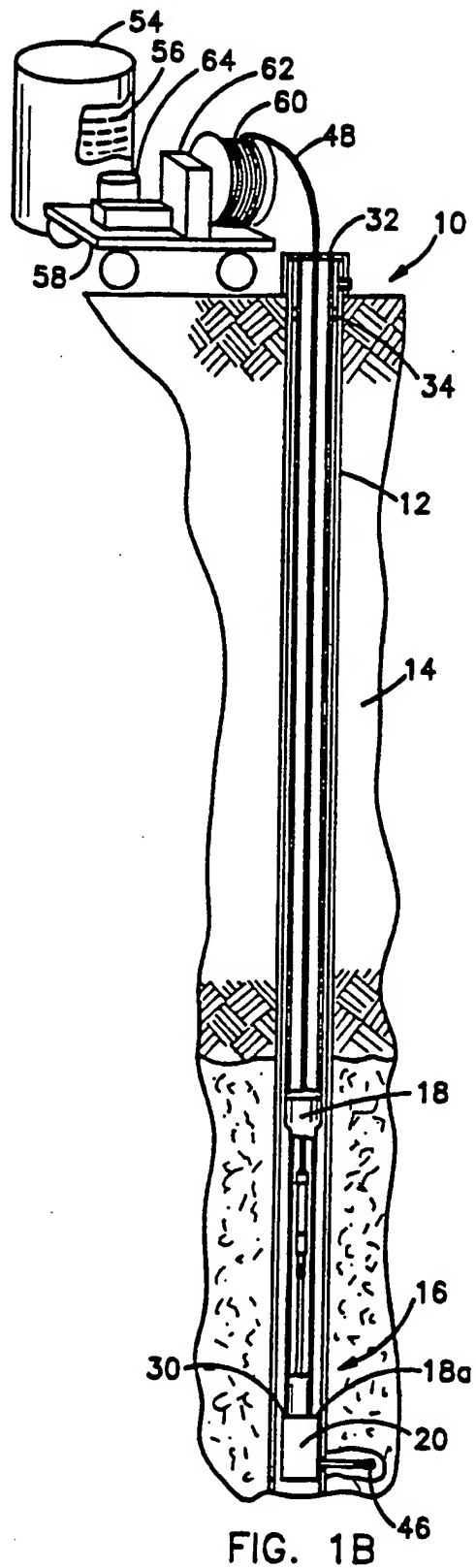
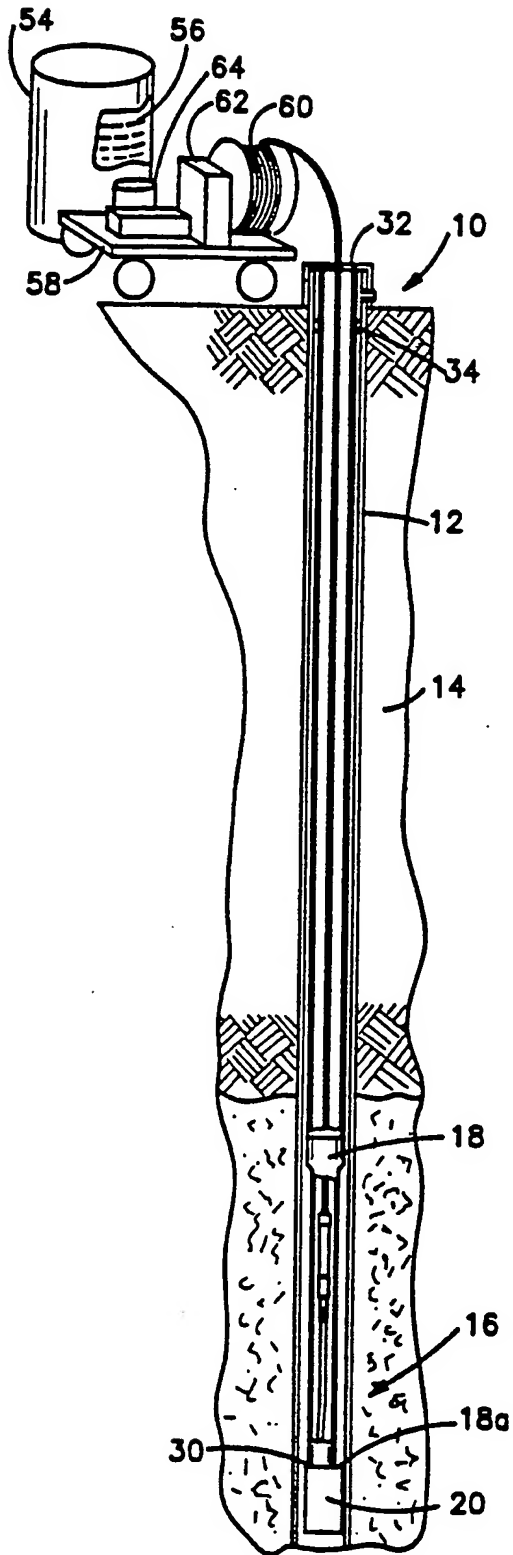
23.. The apparatus of Claim 19 wherein said fluid is utilized at a temperature of from about 130°F (54°C) to about 160°F (71°C).

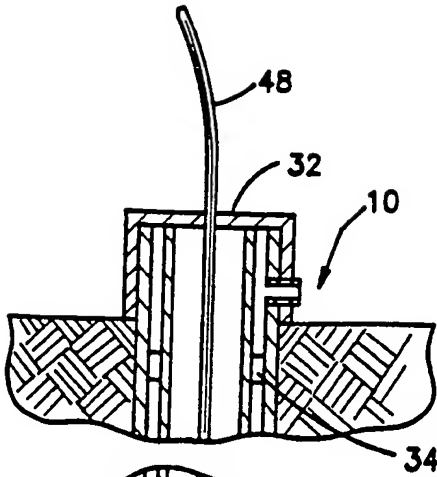
5 24. The apparatus of Claim 10 where said flexible shaft has a plurality of balls thereover, said balls having spacing means therebetween.

25. The apparatus of Claim 24 where said spacing means includes at least one spring.

10 26. The apparatus of Claim 10 where said means to rotate said flexible shaft rotates said flexible shaft at about 225 rpm.

27. The apparatus of Claim 18 where said plurality of orifices in said conical portion angle 45°
15 forward away from said well casing and where said plurality of orifices in said base portion angle 45° rearward toward from said well casing.





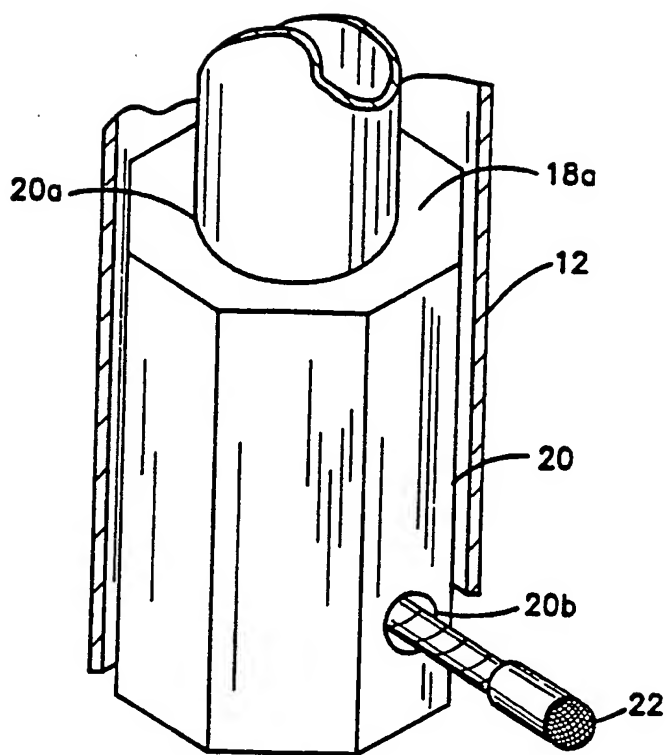


FIG. 3

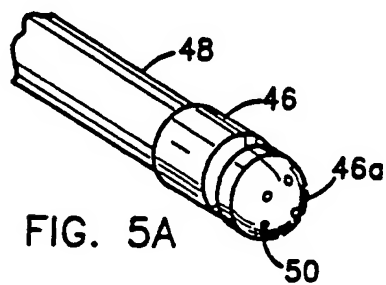


FIG. 5A

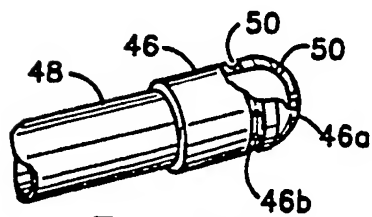
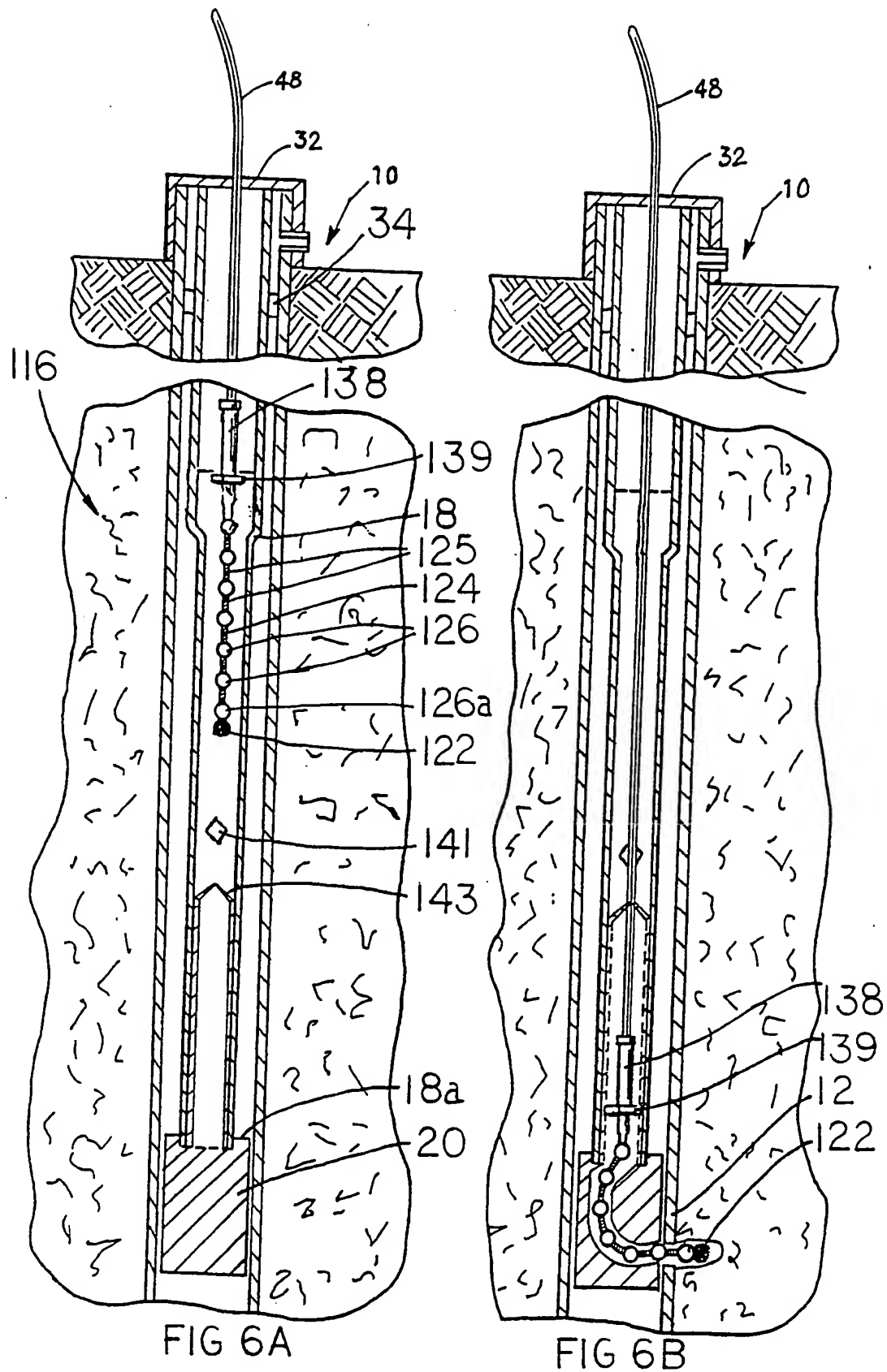


FIG. 5B

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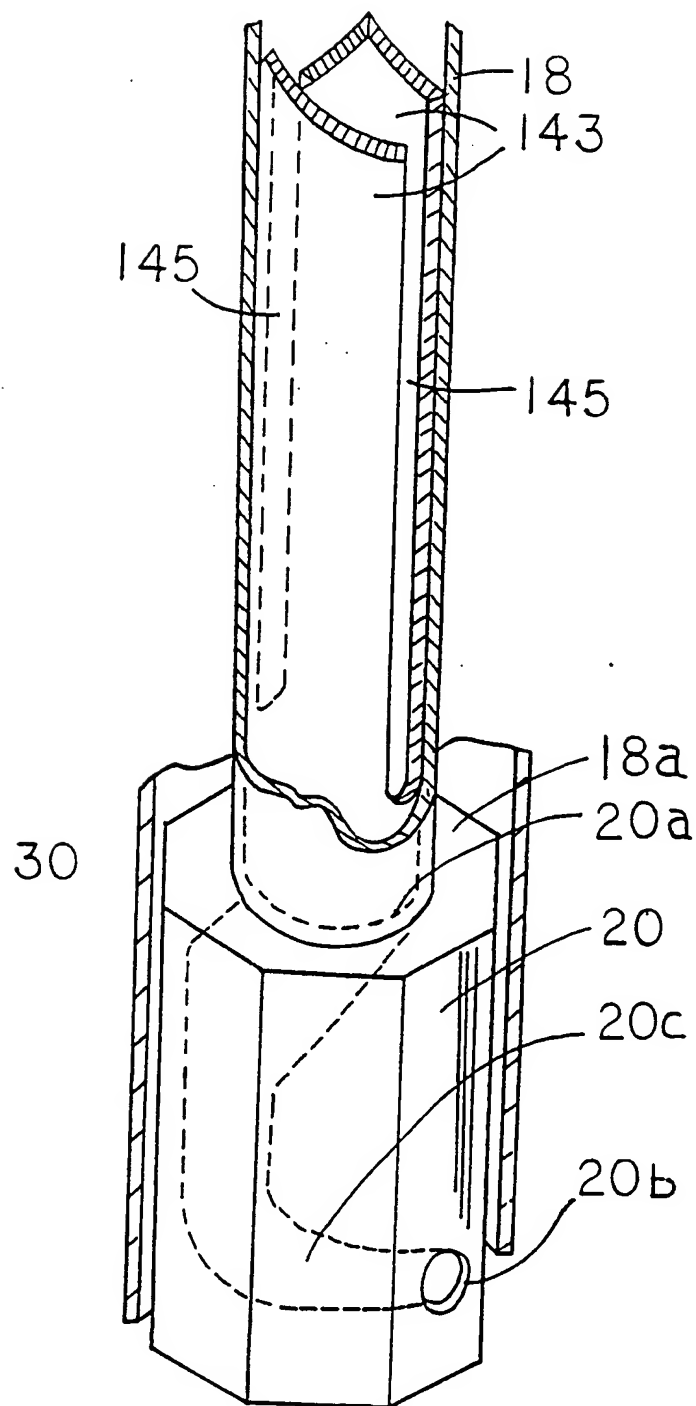


FIG 7

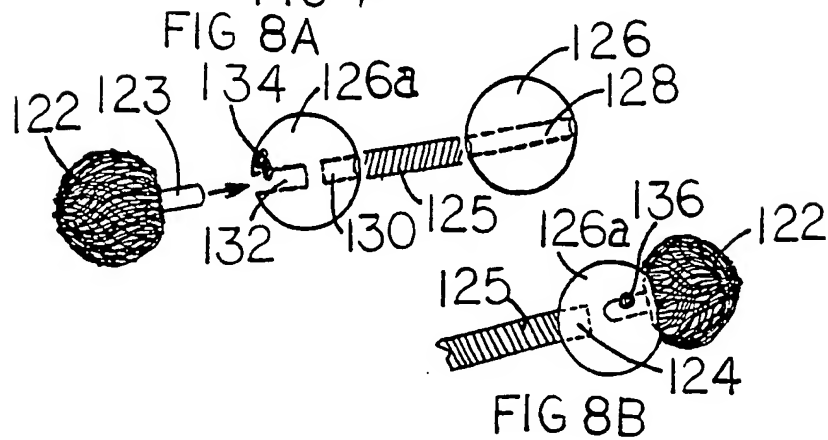


FIG 8B

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 E21B29/06 E21B7/06 E21B17/20 E21B7/18 F16C1/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 E21B B23C F16C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A,4 640 362 (SCHELLSTEDE) 3 February 1987 see column 9, line 53 - column 10, line 10 see column 11, line 3 - line 39; figures 5I,16 ---	16,17
X	FR,A,2 232 669 (INSTITUT FRANÇAIS DU PÉTROLE) 3 January 1975 see page 2, line 25 - line 32; figure 1 ---	10
Y	---	17
X	FR,A,2 091 931 (COMPAGNIE FRANÇAISE DES PÉTROLES) 21 January 1971 see page 7, line 36 - line 40 see page 8, line 6 - line 16; figure 6 ---	10
X	US,A,4 185 705 (BULLARD) 29 January 1980 ---	10
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Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

* Special categories of cited documents:

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Date of the actual completion of the international search

7 February 1995

Date of mailing of the international search report

15.02.95

Name and mailing address of the ISA

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Rampelmann, K

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US,A,3 536 151 (AARUP) 27 October 1970 see figure 4	17
A	---	4,18
A	US,A,4 850 440 (SMET) 25 July 1989 see column 6, line 45 - line 56; figure 3	4,18
A	---	
A	US,A,4 007 797 (JETER) 15 February 1977 see column 4, line 37 - line 43	2,11
A	---	
A	US,A,4 631 136 (JONES) 23 December 1986 see abstract	5-8, 19-22
A	---	
A	DE,C,485 867 (FIRMA AUGUST RÜGGERBERG) 23 December 1927 see figure 1	15
A	---	
A	US,A,5 148 877 (MACGREGOR) 22 September 1992 see figures 14,15	15
A	---	
A	FR,A,702 530 (BARBER) 10 April 1931 see page 1, line 15 - line 29 see page 3, line 46 - line 51; figure 18	24,25
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